

VI.—On the Foraminifera of the River Dee.

By J. D. SIDDALL.

THE Microzoa inhabiting brackish water have formed the subject of much careful study—the Ostracoda especially at the hands of Mr. G. S. Brady and Mr. Robertson, the Foraminifera at those of Mr. H. B. Brady and the latter gentleman. The interest which attaches to an intermediate fauna depends very greatly on the completeness of its ascertained facts even to minute particulars; and it is with this view that the following paper is offered as a contribution to the general store of knowledge. As the observations of which it is the record refer entirely to the Foraminifera, it may be well at the outset to note what has already been done in connexion with the subject.

In his Catalogue of the Foraminifera of the north-eastern portion of the English coast*, Mr. H. B. Brady draws attention to the Rhizopoda inhabiting the brackish pools of one or two river-estuaries, commenting on the apparent alteration in the material of the test in some well-known species as dependent on their altered external conditions of life.

The subject was resumed and entered upon at much greater length by the same author in a paper which appeared in the 'Annals' for October 1870†. This memoir is founded on the examination of material collected from upwards of thirty localities, principally river-estuaries, round Great Britain. In the preliminary observations the question of the chemical and physical characters of the test is further dwelt upon, and the general conclusion drawn that in proportion to the decreased salinity of the water the investment of the testaceous Rhizopoda becomes less and less calcareous, till at last in certain species, which tolerate this process of dilution better than others, the test ceases to be calcareous at all, and consists only of a thin, brown, chitinous membrane, which is not dissolved by either acids or alkalis. The species in which these phenomena were especially noticed were *Trochammina macrescens* and *Quinqueloculina fusca*, the origin of both of which could be traced to well-known marine forms. The sarcode, in like manner, was shown often to acquire a green colour in brackish specimens, apparently from the formation of chlorophyl.

* "Catalogue of the Recent Foraminifera of Northumberland and Durham," Nat.-Hist. Trans. North. & Durham (1866), vol. i. p. 86.

† "The Ostracoda and Foraminifera of Tidal Rivers," by Geo. S. Brady, C.M.Z.S., and David Robertson, F.G.S.; with an Analysis and Descriptions of the Foraminifera by Henry B. Brady, F.L.S. (Part II.) Ann. & Mag. Nat. Hist. ser. 4, vol. vi. pp. 273-306, pls. xi. & xii.

Out of the forty-four genera constituting the British marine fauna, representatives of thirty-two were observed and recorded from these gatherings: some types were conspicuous by their absence, whilst others, especially the *Milioline* genera, with *Truncatulina*, *Rotalia*, *Polystomella*, and *Nonionina*, appeared to adapt themselves to brackish water perfectly. After tracing the relation of the existing brackish-water Foraminiferous fauna of the "Fen area" with that of the Post-tertiary Fen-clays, Mr. Brady proceeds to give a geographical account of the stations from which the material had been collected, and also of the various species found, concluding a valuable and comprehensive paper with a table showing the genera and species found in each locality.

More recently* Mr. David Robertson, F.G.S., of Glasgow, has worked out, with great care and patience, the Foraminifera of the Firth of Clyde; and his results yield a list of eighty-five species in all. His gatherings were made at no less than forty stations, and embrace depths of all degrees from four to thirty fathoms. Between these extremes there must be a wide range of variation in the conditions of life, depending on the depth and on the relative volume of fresh and salt water; and fuller particulars on such points would have conferred additional interest upon Mr. Robertson's valuable paper.

The results proposed to be offered in the following pages have been attained from the examination of the Microzoa of the estuary of the Dee, the observations having extended over a period of about three years—great assistance having been given in this by my kind friend Mrs. Shone, who has worked most indefatigably, and discovered several species of great interest. The list is even a longer one than Mr. Robertson's, comprising no less than one hundred species and varieties, an increase of fifteen per cent. in number. Of the thirty-two genera included in Mr. Brady's list, three have not yet been observed in the Dee, viz. *Glandulina*, *Vaginulina*, and *Gaudryina*; but three others have taken their place, and so made the number equal, viz. *Bigenerina*, *Spirillina*, and *Cassidulina*; but the specimens of each are very small and of rare occurrence.

The estuary of the Dee from Chester down to Burton Point, a distance of about 9 miles, has within the past two hundred years undergone very considerable changes in outline. Many thousands of acres of sand which the tide formerly flowed over have been reclaimed; and this work of reclamation is still

* "Notes on the Ostracoda and Foraminifera of the Firth of Clyde, with some Remarks on the Distribution of Mollusca," by David Robertson, F.G.S., Trans. Geol. Soc. Glasgow, 1874, vol. v. part 1, p. 112.

going on; and as the amount of tidal water which reaches Chester and Saltney must of necessity be very much lessened by reason of the narrowing of the channel through which it flows, the character of the fauna of this part of the river will doubtless be greatly altered. An opportunity of verifying this deduction, by comparing the Foraminifera which are very plentiful in the reclaimed sands with specimens collected fresh from the river, has been afforded by some excavations that have been going on during the past year; and these comparisons show that in the "sands" there is an almost total absence of the thin-shelled "chitinous" forms now so common in the river at the same distance from the sea. There can be no doubt that the degree of salinity of the water has a marked effect upon these lowly organisms; and it is to be regretted that a series of careful observations was not made to ascertain this at the different points from which collections of Foraminifera have been made. The importance of this was not then fully realized; but it is hoped that the omission will be rectified during the ensuing summer, when it is proposed that the Entomostraca shall be worked out.

The Dee, with its wide estuary, might reasonably be expected to be very rich in Rhizopoda; and such proves to be the case, the annexed List showing how very numerous its Foraminifera are. Living specimens have as yet been obtained only from the lower parts of the river, near to the sea; but the richest deposits of dead shells are found near to Chester and Saltney, about 18 miles from the sea, where they are brought and deposited by the tide. Material for examination has been collected from all parts of the river, but more particularly from the following:—

No. 1. Chester (18 miles from the sea; water not perceptibly saline, except at high water). A sand bank left bare at low water; sand collected at high- and low-water marks. During spring tides very rich.

No. 2. Saltney (16 miles from the sea; water as in last). A sand bank completely covered each tide; sand collected from between the ripple-marks at extreme low water. The richest collecting-ground yet found in the whole river. This and no. 1 seem to owe their peculiar richness to their position, being situated in each case at a bend in the river. Dredgings between these points yielded very little.

No. 3. Queen's Ferry (11 miles from the sea; water slightly brackish). Sand collected from sheltered spots at low-water mark; also dredged. Not very productive.

No. 4. Connah's Quay (9 miles from the sea; water decidedly brackish). Shore-sand from here not very rich, but

dredgings yield a considerable number of arenaceous specimens.

No. 5. Burton Marsh (8 miles from the sea ; estuary widening rapidly ; water rather salt). The material examined from here was scraped from the channels and pools left by the receding tide. It contained Foraminifera, but nothing requiring special comment.

No. 6. Parkgate (estuary 2 miles wide ; water salt). Sand scraped from low-water mark on the shore, also dredged. Not very good.

No. 7. Holywell (estuary 4 miles wide). Collections made by scraping and skimming the "grassy" pools on the muddy shore near high-water mark, and also the sandy mud at low-water mark. In a very rich gathering of Rhizopoda made here on the 19th of April, 1875, *Gromia oviformis* and *Diffugia pyriformis* and *aculeata* were very plentiful; and some very fine living specimens of *Polystomella striato-punctata* then obtained were afterwards kept under observation for several days. They were for a few days particularly active, and crawled about the cells in which they were placed for examination. After two or three days, however, the pseudopodia of some became finally retracted, and the sarcode showed a tendency to become granulated and condensed into an oval mass in the centre of each chamber of the shell; the following note, having reference to this aggregation of the sarcode, was made at the time:—
 ". . . Twelve chambers of shell visible externally. The granular oval contents of chambers nos. 2, 4, and 9 (from the aperture) were furnished with cilia, distinctly visible with a power of 400 diameters, and swam freely about in the chambers; on the contents of the other chambers no cilia were visible, and the form assumed by the contracted sarcode was not so definite. Colour of sarcode brownish yellow ; moving bodies rather more dense, and therefore very slightly darker in colour." The cilia were very plain ; and the writer was corroborated in his observation by the Rev. J. L. Bedford, F.L.S., who was present at the time.

No. 8. Hilbre Island (estuary 5 miles wide). The material collected here from among the rocks between the "Little Eye" and "Middle Island," at dead low water, and also that from no. 7, were very good gatherings, and especially rich in arenaceous forms. The difference in the appearance of the shells obtained from these "salt-water" localities and of those from nearer Chester, where the water is scarcely "brackish," was very marked—the specimens from the former having fine well-developed shells, while those from the latter sources are generally small and delicate, and often destitute of any calcareous matter

in the "test," especially in the representatives of the Milioline genera, its place being supplied by the "chitinous" or reddish-brown horny-looking substance which seems to form the base of the shell in all the *Miliolinæ*.

It is interesting to compare the Rhizopodal fauna of these two western estuaries, the Clyde and the Dee. Of the total number of forms met with, sixty-nine are common to both rivers; seventeen species are found in the Clyde which have not been found in the Dee, and, on the other hand, thirty-two have been found in the last-mentioned river which do not appear in Mr. Robertson's catalogue, as follows:—

Foraminifera found in the Firth of Clyde not occurring in the estuary of the Dee.

Cornuspira foliacea.
Triloculina Brongniartii.

Spiroloculina excavata.
Lituola nautiloidea.
Valvulina austriaca.
Lagena distoma.
—— lagenoides.
—— hexagona.
—— Jeffreysii.
—— striato-punctata.
Nodosaria pyrula.
Dentalina pauperata.
Vaginulina legumen.

Polymorphina tubulosa.

Bulimina aculeata.

Tinoporos lucidus.

Polystomella arctica.

Foraminifera found in the estuary of the Dee not occurring in the Firth of Clyde.

Cornuspira involvens.

Quinqueloculina Candaina.
—— pulchella.

Lituola fusiformis.

Lagena striata, var. gracilis.
—— ornata.
—— lucida.
—— aspera.

Nodosaria radícula.
Dentalina guttiferá.

Marginulina raphanus.
—— glabra.
Polymorphina oblonga.
—— Thouini.
—— fusiformis.
—— concava.
—— gibba, var. æqualis.

Uvigerina angulosa.

—— pygmæa.
Textularia pygmæa.
—— difformis.
—— agglutinans.

Verneuilina spinulosa.
Bulimina elegantissima.
Bigenerina digitata.
Spirillina margaritifera.
—— vivipara.

Cassidulina lævigata.

Truncatulina refulgens.
Pulvinulina aurícula.
—— repanda.

Nonionina umbilicatula.

Of the Foraminifera in the Dee catalogue, three forms are new to the British fauna, and deserve a moment's notice; and attention may just be called to the fact of the appearance of *Verneuilina spinulosa*, which is an interesting confirmation of its previous record by Mr. Brady.

Cornuspira involvens, Reuss.

Operculina involvens, Reuss, 1849, Denkschr. Akad. Wien, vol. i. p. 370, pl. xlv. fig. 20.

Cornuspira involvens, Jones, Parker, and Brady, 1865, Monog. Crag Forum. p. 3, pl. iii. figs. 52-54.

Messrs. Jones, Parker, and Brady (*loc. cit.*) admit Professor Reuss's name for the thicker *Cornuspira* with rounded tube, as distinct from the outspread flattened contour of *C. foliacea*. Probably the real zoological significance of the character is not great; but it seems quite worth recognizing.

Lagena aspera, Reuss.

Lagena aspera, Reuss, 1861, Sitzungsab. d. k. Akad. Wiss. Wien, vol. xl. p. 305, pl. i. fig. 5.

A rare species, with superficial rugosity caused by small, short, blunt spines. Well figured by Professor Reuss from fossil Tertiary specimens, but not figured in any English work.

Polymorphina Thouini, D'Orbigny.

Polymorphina Thouini, D'Orbigny, 1826, Ann. Sci. Nat. vol. vii. p. 265. no. 8, Modèle no. 23; Brady, Parker, and Jones, 1870, Trans. Linn. Soc. Lond. vol. xxvii. p. 232, pl. xl. fig. 17.

An interesting and exceedingly well-marked variety, of which one very beautiful specimen was obtained. It has an attenuated subcylindrical contour, with long, upright, compactly fitting segments.

Great interest was constantly manifested in the prosecution of these researches by the late Rev. Canon Kingsley, the founder and President of our Chester Society of Natural Science. Those whose privilege it was to know him will best appreciate the weight and value of his encouragement in such a work.

In conclusion, it remains only to state that all doubtful forms, and in fact the whole series of mountings, have with characteristic kindness been carefully examined by Mr. H. B. Brady, F.R.S., whose revision is an assurance of uniformity of nomenclature with previously published researches on the same subject, a matter of some importance in so variable a group of organisms.

FORAMINIFERA OF THE RIVER DEE.
*Tabulated List, showing the Distribution and Relative Abundance of each Species between Chester and
 Hilbre Island.*

Types.	Genera and Species.	Locality.	Remarks.
Suborder IMPERFORATA. Family MILIOLIDA. Cornuspira foliaceae, <i>Phil.</i> } } Miliola seminulum, <i>Lin.</i> }	Cornuspira, <i>Schultze.</i> <i>involvens, Reuss</i>	Chester to Hilbre.	Rather rare.
	Biloculina, <i>D'Orb.</i> <i>ringens, Lamk.</i> <i>elongata, D'Orb.</i> <i>depressa, D'Orb.</i>	Chester to Hilbre. " " " "	Very rare. Frequent. Common.
	Triloculina, <i>D'Orb.</i> <i>oblonga, Montagu</i> <i>tricarinata, D'Orb.</i> <i>trigona, D'Orb.</i>	Chester to Hilbre. Saltney. Chester to Hilbre.	Common. A single specimen only. Frequent.
	Quinqueloculina, <i>D'Orb.</i> <i>agglutinans, D'Orb.</i> <i>seminulum, Lin.</i> <i>pulchella, D'Orb.</i> <i>bicornis, W. & J.</i> <i>secans, D'Orb.</i> <i>subrotunda, Montagu</i>	Holywell and Hilbre. Chester to Hilbre. Saltney. Chester to Hilbre.	Rare. Rather rare. A single specimen only. Frequent, especially young shells. Frequent.
	Candaina, <i>D'Orb.</i> <i>fusca, Brady</i> <i>Spiroloculina, D'Orb.</i> <i>planulata, Lamk.</i> <i>canaliculata, D'Orb.</i> <i>limbata, D'Orb.</i>	" " Saltney. " " Holywell. Chester to Hilbre. " " Hilbre.	A single specimen only. A single specimen only. A single specimen only. Rather rare. Rather rare. Very rare. A single specimen only.

Types.	Genera and Species.	Locality.	Remarks.
Family LITUOLIDA. Trochammina squamata, <i>P. & J.</i> Litnola nautiloidea, <i>Lamb.</i>	Trochammina, <i>P. & J.</i> incerta, <i>D'Orb.</i> gordialis, <i>P. & J.</i> squamata, <i>P. & J.</i> macrescens, <i>Brady</i> inflata, <i>Montagu</i> Litnola, <i>Lamb.</i> canariensis, <i>D'Orb.</i> scoriipurus, <i>Montf.</i> fusiformis, <i>Will.</i>	Hilbre. Holywell. " " Chester to Hilbre. Chester to Hilbre. Hilbre. Holywell and Hilbre.	Very rare. Very rare. One <i>good</i> specimen only. Rare. Not common. Common. Common. Very rare. Very rare.
Suborder PERFORATA. Family LAGENIDA. Lagena, <i>Walker.</i> sulcata, <i>W. & J.</i> Lyelli, <i>Sequenza</i> lævis, <i>Montagu</i> gracillima, <i>Sequenza</i> striata, <i>D'Orb.</i> var. <i>gracilis, Will.</i> .. semistriata, <i>Will.</i> globosa, <i>Montagu</i> marginata, <i>W. & J.</i> ornata, <i>Will.</i> pulchella, <i>Brady</i>	Chester to Hilbre. " " " Holywell. Chester to Hilbre. " " " Hilbre.	Rather common. Very rare. Rather common. Rather rare. Frequent. Very rare. Frequent. Rather common. Frequent. Rare. Very rare.	

lucida, <i>Will.</i>	Chester to Hilbre.	Frequent.
aspera, <i>Reuss.</i>	"	Very rare.
caudata, <i>D'Orb.</i>	"	Not common.
melo, <i>D'Orb.</i>	"	Frequent.
squamosa, <i>Montagu</i>	"	Frequent.
Nodosaria, <i>Lamk.</i>		
<i>scalaris, Batsch.</i>	Chester to Hilbre.	Rare. Very variable in form.
<i>radicula, Linn.</i>	Holywell and Hilbre.	Very rare.
<i>Dentalina, D'Orb.</i>		
<i>guttifera, D'Orb.</i>	Chester to Hilbre.	Rather rare. Perfect specimens at Hilbre.
<i>communis, D'Orb.</i>	"	Frequent.
<i>Marginulina, D'Orb.</i>	Saltney.	A single specimen only.
<i>raphanus, D'Orb.</i>	"	A single specimen only.
<i>glabra, D'Orb.</i>		
<i>Cristallaria, Lamk.</i>		
<i>rotulata, Lamk.</i>	Chester to Hilbre.	Rare. Generally small.
<i>crepidula, F. & M.</i>	"	Frequent.
<i>Polymorphina, D'Orb.</i>		
<i>communis, D'Orb.</i>	Chester to Hilbre.	Frequent.
<i>compressa, D'Orb.</i>	"	Frequent.
<i>oblonga, Will.</i>	"	Rather common.
<i>Thouini, D'Orb.</i>	Hilbre.	A single specimen only.
<i>fusiformis, Roemer</i>		A single specimen only.
<i>lactea, W. & J.</i>	Chester to Hilbre.	Not common.
<i>concava, Will.</i>	"	Rare.
<i>gibba, D'Orb.</i>	"	Frequent.
<i>var. aequalis, D'Orb.</i>	"	Frequent.
<i>Uvigerina, D'Orb.</i>		
<i>angulosa, Will.</i>	Chester to Hilbre.	Small and rare.
<i>pygmaea, D'Orb.</i>	"	Small and rare.
Nodosaria raphanus, <i>Linn.</i>		
Polymorphina lactea, <i>W. & J.</i>		
Uvigerina pygmaea, <i>D'Orb.</i>		

Types.	Genera and Species.	Locality.	Remarks.
Family GLOBIGERINIDA.			
Orbulina universa, <i>D'Orb.</i>	Orbulina, <i>D'Orb.</i> universa, <i>D'Orb.</i>	Chester to Hilbre.	Rare. Test generally brown.
Globigerina bulloides, <i>D'Orb.</i>	Globigerina, <i>D'Orb.</i> bulloides, <i>D'Orb.</i>	Chester to Hilbre.	Not common.
Textularia agglutinans, <i>D'Orb.</i>	Textularia, <i>DeFrance.</i> sagittula, <i>DeFrance</i> variabilis, <i>Will.</i> pygmaea, <i>D'Orb.</i> difformis, <i>Will.</i> agglutinans, <i>D'Orb.</i>	Holywell and Hilbre. Chester to Hilbre. " Hilbre. Holywell and Hilbre.	Very rare. Frequent. Very rare. Specimens very small. Very rare. Specimens very small. Very rare.
Verneuilina, <i>D'Orb.</i>	Verneuilina, <i>D'Orb.</i> spinulosa, <i>Reuss</i> polystropha, <i>Reuss</i>	Saltney. Connah's Quay to Hilbre.	A single specimen only. Rare.
Bulimina, <i>D'Orb.</i>	Bulimina, <i>D'Orb.</i> pupoides, <i>D'Orb.</i> marginata, <i>D'Orb.</i> ovata, <i>D'Orb.</i> elegantissima, <i>D'Orb.</i> ...	Chester to Hilbre. " " " "	Rather rare. Rather rare. Frequent. Rather rare.
Bulimina Presli, <i>Reuss</i>	Virgulina, <i>D'Orb.</i> Schreibersii, <i>Czizek</i> Bolivina, <i>D'Orb.</i> punctata, <i>D'Orb.</i> plicata, <i>D'Orb.</i>	Chester to Hilbre. Chester to Hilbre. " "	Very rare. Good specimen. Rare. Not common.
Spirillina vivipara, <i>Ehrenb.</i>	Bigenerina, <i>D'Orb.</i> digitata, <i>D'Orb.</i> Spirillina, <i>Ehrenberg.</i> margaritifera, <i>Will.</i> vivipara, <i>Ehrenb.</i>	Hilbre and Holywell. Chester. Chester to Hilbre.	Rare, and always broken. A single specimen only. Very rare.

Cassidulina levigata, <i>D'Orb.</i>	Cassidulina, <i>D'Orb.</i> levigata, <i>D'Orb.</i>	Saltney.	Very rare and small.
Discorbina turbo, <i>D'Orb.</i>	Discorbina, <i>P. & J.</i> rosacea, <i>D'Orb.</i> globularis, <i>D'Orb.</i> ochracea, <i>Will.</i>	Chester to Hilbre. " Holywell.	Not common. Frequent. Very fine. Very rare. Specimens very small.
Planorbulina fareta, <i>F. & M.</i>	Planorbulina, <i>D'Orb.</i> mediterraneensis, <i>D'Orb.</i> Truncatulina, <i>D'Orb.</i> lobatula, <i>Walker</i> refulgens, <i>Montfort</i>	Chester to Hilbre. Chester to Hilbre. Holywell.	Frequent. Occasionally " <i>Acerrulina</i> ." Common. Very fine. A single specimen only.
Pulvinulina repanda, <i>F. & M.</i>	Pulvinulina, <i>P. & J.</i> auricula, <i>F. & M.</i> repanda, <i>F. & M.</i>	Saltney. Hilbre.	Very rare. Very rare.
Rotalia Beccarii, <i>Linn.</i>	Rotalia, <i>Lamb.</i> Beccarii, <i>Linn.</i> nitida, <i>Will.</i>	Chester to Hilbre. "	Common. Very fine. Not common. Generally small.
Patellina concava, <i>Lamb.</i>	Patellina, <i>Will.</i> corrugata, <i>Will.</i>	Chester to Hilbre.	Rare. Good specimens.
Family NUMMULINIDA.			
Polystomella crispa, <i>Linn.</i>	Polystomella, <i>Lamb.</i> crispa, <i>Linn.</i> striata-punctata, <i>F. & M.</i>	Holywell and Hilbre. Chester to Hilbre.	Very rare. Poor specimens. Abundant. Very fine.
	Nonionina, <i>D'Orb.</i> scapha, <i>F. & M.</i> depressula, <i>W. & J.</i> umbilicatula, <i>Montf.</i> turgida, <i>Will.</i> asterizans, <i>F. & M.</i>	Chester to Hilbre. " Hilbre. Chester to Hilbre. "	Very rare. Good specimens. Abundant and fine. Very rare. Generally broken. Rather rare.